3729 #6 BT 03-11-02

PATENT

IN THE UNITED STATES PATENT
AND TRADEMARK OFFICE

Applicants: Temple et al.	)	I hereby certify that this paper (or fee) is being deposited with the United States Postal Service, first class postage prepaid, addressed to: Commissioner for Patents, Washington, DC 20231.
Serial No.: 09/853,520	)	
Filed: May 11, 2001	)	
For: DROPLET DEPOSITION APPARATUS	)	October 25, 2001
Group Art Unit: 3729	)	
Examiner: To be assigned	)	James P. Zeller Reg. No. 28,491

SUBMISSION OF PRIORITY DOCUMENT

Commissioner for Patents
Washington, DC 20231

Sir:

Submitted herewith are certified copies of Great Britain 9824998.0 filed November 14, 1998, and Great Britain 9919201.5 filed August 14, 1999, the priority of which are claimed under 35 U.S.C. § 119.

Respectfully submitted,

MARSHALL, GERSTEIN & BORUN

October 25, 2001

By _____
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The Patent Office
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Cardiff Road
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I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

I also certify that the attached copy of the request for grant of a Patent (Form 1/77) bears an amendment, effected by this office, following a request by the applicant and agreed to by the Comptroller-General.

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Signed

Dated 25 May 2001

Patent Form 1/77

Patents Act 1977
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The Patent Office

1/77

16NOV98 E404840-1 C40442
P01/7700 0.00 - 9824998.0

Request for grant of a patent

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The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

1. Your reference

X342

2. 9824998.0

14 NOV 1998

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Xaar Technology Limited
Science Park
Milton Road
Cambridge
CB4 0XR

Patents ADP number *(if you know it)*

If the applicant is a corporate body, give the country/state of its incorporation

UK 7301872001

4. Title of the invention

Droplet Deposition Apparatus

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

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1081001

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FS1/77
28/9/99

Patents ADP number *(if you know it)*

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
-----		

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*
-----	

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*

a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d))

YES

Patents Form 1/77

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Continuation sheets of this form	-----
Description	8 JDSH
Claim(s)	-----
Abstract	-----
Drawing(s)	9 + 9

10. If you are also filing any of the following, state how many against each item.

Priority documents	-----
Translations of priority documents	-----
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	-----
Request for preliminary examination and search *(Patents Form 9/77)*	-----
Request for substantive examination *(Patents Form 10/77)*	-----
Any other documents *(please specify)*	-----

11. I/We request the grant of a patent on the basis of this application.

Signature I. Hartwell Date 13/11/98

12. Name and daytime telephone number of person to contact in the United Kingdom: Ian Hartwell (01223) 423663

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Droplet Deposition Apparatus

The present invention relates to droplet deposition apparatus, particularly inkjet printheads.

Figure 1 shows a prior art inkjet printhead 1 of the kind disclosed in WO91/17051 and comprising a sheet 3 of piezoelectric material, suitably lead zirconium titanate (PZT), formed in a top surface thereof with an array of open-topped ink channels 7. As evident from figure 2, which is a sectional view taken along line AA of figure 1, successive channels in the array are separated by side walls 13 which comprise piezoelectric material poled in the thickness direction of the sheet (as indicated by arrow P). On opposite channel-facing surfaces 17 are arranged electrodes 15 to which voltages can be applied via connections 34. As is known, e.g. from EP-A-0 364 136 application of an electric field between the electrodes on either side of a wall results in shear mode deflection of the wall into one of the flanking channels, generating a pressure pulse in that channel.

The channels are closed by a cover 25 in which are formed nozzles 27 each communicating with respective channels at the mid-points thereof. Droplet ejection from the nozzles takes place in response to the aforementioned pressure pulse, as is well known in the art. Supply of droplet fluid into the channel, indicated by arrows S in figure 2, is via two ducts 33 cut into the bottom face 35 of the sheet 3 to a depth such that they communicate with opposite ends respectively of the channels 7. A cover plate 37 is bonded to the bottom face 35 to close the ducts.

Figures 3 and 4 are exploded perspective and sectional views respectively of a "pagewide" printhead of the kind disclosed in co-pending PCT application no. PCT/GB98/01495 and extending in a direction "W" transverse to a media feed direction P. As shown in figure 4, which is a sectional view taken perpendicular to the direction W, two piezoelectric bodies 82a, 82b each having channels and electrodes as described above are closed by a substrate 86 in

which openings 96a,96b for droplet ejection are formed. Respective supply chambers at the ends of the channels in each body, namely supply chambers 88 and 90 at either end of body 82a and supply chambers 90 and 92 at either end of body 82b, are defined between the substrate 86 and a base 80. Respective channel electrodes are connected to conductive tracks (not shown) on the substrate 86 which also carry respective driver chips 84a and 84b located in further chambers 94a,94b defined by the base 80. Understandably, the further chambers 94a,94b are sealed from supply chambers 88 and 92.

The channel-closing substrate 86 with conductive tracks for conveying electrical signals to actuator means located in the channels and openings 96a,96b for droplet ejection acts as a support member for the bodies 82a and 82b. As will be evident from figure 3, bodies 82 and drive chips 84 are aligned and fixed to the substrate 86 - which in turn can be made to such a size as to be easy to handle during manufacture.

As illustrated in figure 3, bodies 82 may be butted together to form a single, contiguous, pagewide array of channels - described in WO91/17051 and consequently not in any further detail here - in which case the substrate 86 serves to support the individual bodies both during and after the butting process. Such bodies may be tested before assembly, thereby reducing the chances of a complete printhead being faulty.

The substrate is suitably made of a robust material - such as aluminium nitride, INVAR or special glass AF45 - that has similar thermal expansion characteristics to the piezoelectric material of the bodies. It will be appreciated that the requirement for thermal matching between bodies and substrate is reduced where there is a gap between successive butted bodies (the gap advantageously being filled with glue bond material as mentioned in the aforementioned WO91/17051) in which case a less well thermally-matched material such as alumina can be used.

Droplet ejection opening 96a may itself be formed with a taper or the tapered shape may be formed in a nozzle plate 98 mounted over the opening. Such a nozzle plate may comprise any of the readily-ablatable materials such as

polyimide, polycarbonate and polyester that are conventionally used for this purpose.

Furthermore, nozzle manufacture can take place independently of the state of completeness of the rest of the printhead: the nozzle may be formed by ablation from the rear prior to assembly of the active body 82a onto the substrate 86 or from the front once the active body is in place. Both techniques are known in the art. The former method has the advantage that the nozzle plate can be replaced or the entire assembly rejected at an early stage in assembly, minimising the value of rejected components. The latter method facilitates the registration of the nozzles with the channels of the body when assembled on the substrate.

The construction of figures 3 and 4 has two rows of nozzles formed in a single nozzle plate extending over both the openings 96a,96b in substrate 86 and extending the full length of the substrate. Following the mounting of a corresponding two rows of bodies 82a,82b and drive chips 84a,84b onto the substrate 86 and suitable testing - as described, for example, in EP-A-0 376 606 - base 80 can be attached, thereby to define manifold chambers 88,90 and 92. Chamber 90 supplies the ends of channels formed in both bodies 82a,82b whilst chambers 88 and 92 supply the other ends of the channels in bodies 82a,82b respectively. Conduits through which ink is supplied from the outside of the printhead to each chamber are indicated by dashed lines at 88',90' and 92'. It will be evident that this results in a particularly compact construction in which ink can be circulated from common manifold 90, through the channels in each of the bodies (for example to remove trapped dirt or air bubbles) and out through chambers 88 and 92.

As is known, e.g. from WO95/07820, it is desirable to coat the electrodes and connection tracks of a printhead of the kind described above with a passivant layer in order to inhibit electrolysis and bubble formation or corrosion. The inorganic layer of silicon nitride or similar proposed in this latter document has effective when used in conjunction with electrodes and tracks formed by the

well-known method of electroless deposition (see, for example, EP- A-0 505 065 in this regard). It is one object of the present invention to provide a printhead construction that is particularly suited to these techniques.

Accordingly, the present invention consists in one aspect in a printhead of the kind described above and further comprising a first layer; a second layer which includes piezoelectric material and which is bonded to the first layer; open-topped channels formed in at least said second layer and defining actuator walls therebetween; electrodes formed on channel-facing surfaces of said actuating walls and electrically connected to conductive tracks formed on the first layer; and a third layer that serves to close said channels on all sides lying parallel to the channel axis.

Further aspects of the invention are set out in the description that follow, which concerns an example only and which makes reference to the following figures:

Figure 5 is an assembled sectional view, similar to that of figure 4, of a printhead according to a first embodiment of the invention;

Figure 6 is a cross-sectional view of a channel of the printhead of figure 4;

Figure 7 is a view similar to that of figures 4 and 5 according to a second embodiment of the invention;

Figure 8 is a cross-sectional view through a channel of the printhead of figure 7;

Figure 9 is a view of a third embodiment of the invention;

Figure 10 is a view of fourth embodiment of the invention.

Reference is first made to figure 5, which is a sectional view similar to that of figure 4 and illustrating a printhead of the kind discussed with regard to figures 1-4 and in accordance with the present invention. Wherever features are common with the embodiments of figure 1-4, the same reference figures as used in figures 1-4 have been used.

As with the previous embodiments, the printhead of figure 5 comprises a "pagewide" substrate 86 on which two rows of integrated circuits 84 are mounted. Inbetween lies a row of channels 82 formed in the substrate 84, each of which communicates with two spaced nozzles 96a, 96b for droplet ejection and with manifolds 88,92 and 90 arranged to either side and between nozzles 96a,96b respectively for ink supply and circulation.

In contrast to the printhead embodiments discussed above, the piezoelectric material for the channel walls is incorporated in a layer 100 made up of two strips 110a, 110b. As in the embodiment of figure 4, these strips will be butted together in the pagewidth direction W, each strip extending approximately 5-10 cm (this being the typical dimension of the wafer in which form such material is generally supplied). Prior to channel formation, each strip is bonded to the continuous planar surface 120 of the substrate 86, following which channels are sawn or otherwise formed so as to extend through both strip and substrate. A cross-section through a channel, its associated actuator walls and nozzle is shown in figure 6. Such an actuator wall construction is known, e.g. from EP-A-0 505 065 and consequently will not be discussed in any greater detail.

Following the application of electrode material to the channel walls - as shown at 190 in figure 6 - and to the remainder of the substrate in the form of conductive tracks for connection to drive circuits 84, a cover member 130 is bonded to the substrate and the tops of the channel walls. As will be evident from figure 5, this closes those portions 140a, 140b of each channel which are active by virtue of their walls incorporating piezoelectric material and leaves gaps 150a, 150b, 150c in those inactive parts of the channel to either side of and between portions 140a, 140b. Whilst these gaps can be used for ink flow between channels by themselves, in the embodiment show they are connected to manifolds 88,90,92 which, with their greater cross-sectional area, give a reduced ink flow pressure loss, particularly where there is ink flow in and out of channel portions 140a and 140b via inlet manifold 90 and outlet manifolds 88,92 respectively.

Broadly expressed, the printhead of figure 5 includes a first layer having a continuous planar surface; a second layer of piezoelectric material bonded to said continuous planar surface; at least one channel that extends through the bonded first and second layers; the second layer having first and second portions spaced along the length of the channel; and a third layer that serves to close on all sides lying parallel to the axis of the channel portions of the channel defined by said first and second portions of said second layer.

It will be appreciated that restricting the use of piezoelectric material to those "active" portions of the channel where it is required to displace the channel walls is an efficient way of utilising what is a relatively expensive material. The capacitance associated with the piezoelectric material is also minimised, reducing the load on – and thus the cost of - the driving circuitry.

Similar advantages are obtained with the embodiment of the invention illustrated in figure 7, this time using a single strip 200 of piezoelectric material that sits (and may be bonded) in a trench or cut-out 210 formed in the substrate 86 such that its upper surface 220 lies flush with the upper surface 120 of the substrate. Channels 82 are formed in this assembly in the conventional manner so as to extend through the piezoelectric strip 200 and through the substrate 86 to either side thereof, after which conductive material is applied as described with regard to the previous embodiment.

By appropriately configuring the conductive material – e.g. by means of a break in the plating as described in co-pending PCT application no. PCT/GB98/03050 - it is possible to control the channel walls in one half 140a of the channel 82 independently of the walls in the other half 140b. Adding a cover 130 that closes first and second portions 140a,140b of the channel and that defines ink manifolds 88,90,92 between and to either side of the portions results in a double-row construction of the kind shown in figure 3.

Orifices 96a,96b for ink ejection from the two ink channels thus formed are drilled in the substrate 86, which itself may be formed with a trough 240 on the opposite side to the channels so as to minimise the length of the orifice (and thus potential pressure losses leading to velocity reductions) whilst retaining a

substantial substrate thickness elsewhere. A nozzle plate of the kind discussed with regard to the prior art may of course be arranged in the trough.

This second embodiment of the invention includes the broad concepts of at least one channel having two spaced portions closed on all sides parallel to the channel axis and each communicating with an orifice for ink ejection; a channel section comprising two spaced channel portions and a length of channel therebetween defined by channel walls comprising piezoelectric material; with portions of channel lying to either side of said section in the direction of the channel axis being defined by inactive material.

Figure 8 is a sectional view taken through a channel, its actuator walls and nozzle of the printhead of figure 7. Whilst the polarisation arrows 250 indicate the piezoelectric material of the channel walls to be in a "chevron" configuration of the kind described in EP-A-0 277 703, alternative configurations such as the "monolithic cantilever" of the aforementioned EP-A-0 364 136 are of course possible. Furthermore, depending on the depth to which the channels are sawn (which depth may of course vary due to the shape of the disc cutter used to form the channels – see figure 7, reference figure 260 in this regard), substrate 86 may form part of the channel walls.

In the third invention embodiment shown in figure 9, the piezoelectric material is once again concentrated in two strips 110a, 110b corresponding to two "active" channel lengths 140a,140b which are closed on all sides lying parallel to the channel axis by a cover member 130. Unlike the previous embodiments, however, channel formation is restricted to the strips: substrate 86 is formed with a trench or "bathtub" 300 to the bottom surface 310 of which are bonded the strips. The trench allows free passage for the disc cutter (shown diagrammatically in dashed lines at 320) used in the subsequent sawing step to form the channels in the piezoelectric strips. Trench itself may be formed in the substrate 86 by sawing, grinding, moulding or other suitable means. Outlet holes 96a, 96b for ejection of ink from each of the channel sections 140a,140b are advantageously formed by means of a laser.

Bonding of cover member 130 to the substrate and the tops of the channel walls is preceded as in the previous embodiment by the step of applying conductive material to the channel walls and the surface of the substrate to form actuating electrodes and connection tracks respectively. The latter run from the walls of the channels formed in piezoelectric strips 110a/110b, across the bottom surface 310 of trench 300 and up to respective surfaces 330 of the substrate on which integrated circuits 84 are mounted. As regards the actuating electrodes, these may extend fully or only partially down each side wall so as to define, in combination with the piezoelectric material, actuating walls of the "chevron" or "monolithic cantilever" type as described above.

In bonding the cover 130 to the substrate 86 and to the tops of the channel walls formed in strips 110a/110b, ink manifolds 88,90,92 are formed as described above.

Broadly expressed, the printhead of this third invention embodiment includes a first layer of inactive material; a second layer of piezoelectric material comprising first and second portions formed with channels and bonded to the first layer in a spaced relationship; a third layer that serves to close the channels on all sides lying parallel to their axes; and outlets formed in the first layer for ink ejection from said channels in said portions of the second layer.

The embodiment of figure 10 dispenses with trench 300, the piezoelectric strips 110a, 110b being bonded directly to the continuous planar upper surface 400 of the substrate 86. Whilst this has advantages in terms of reduced machining of the substrate, this may be offset by the need to thicken the cover member 130 to provide the necessary strength at the periphery.

All documents, particularly patent applications, referred to are incorporated in the present application by reference.

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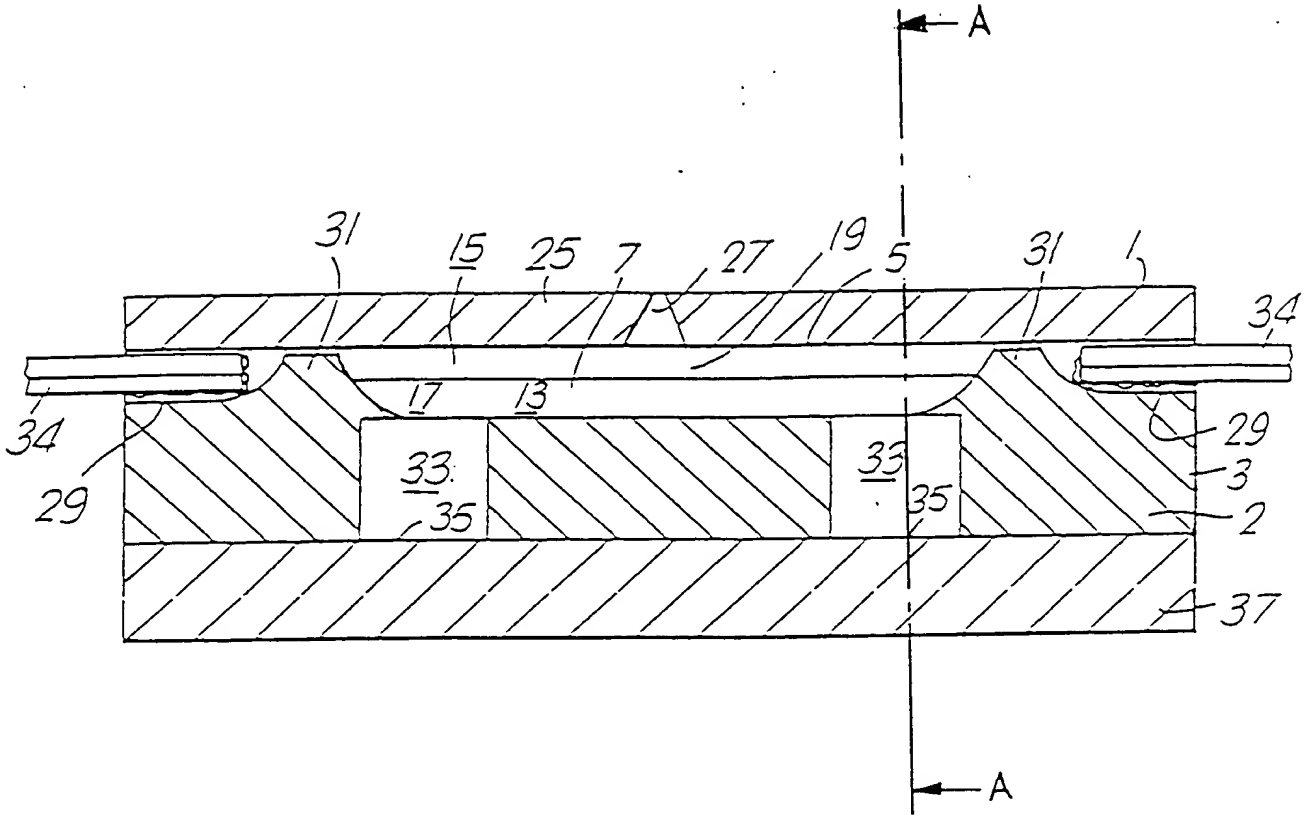

Fig. 1

Fig. 2

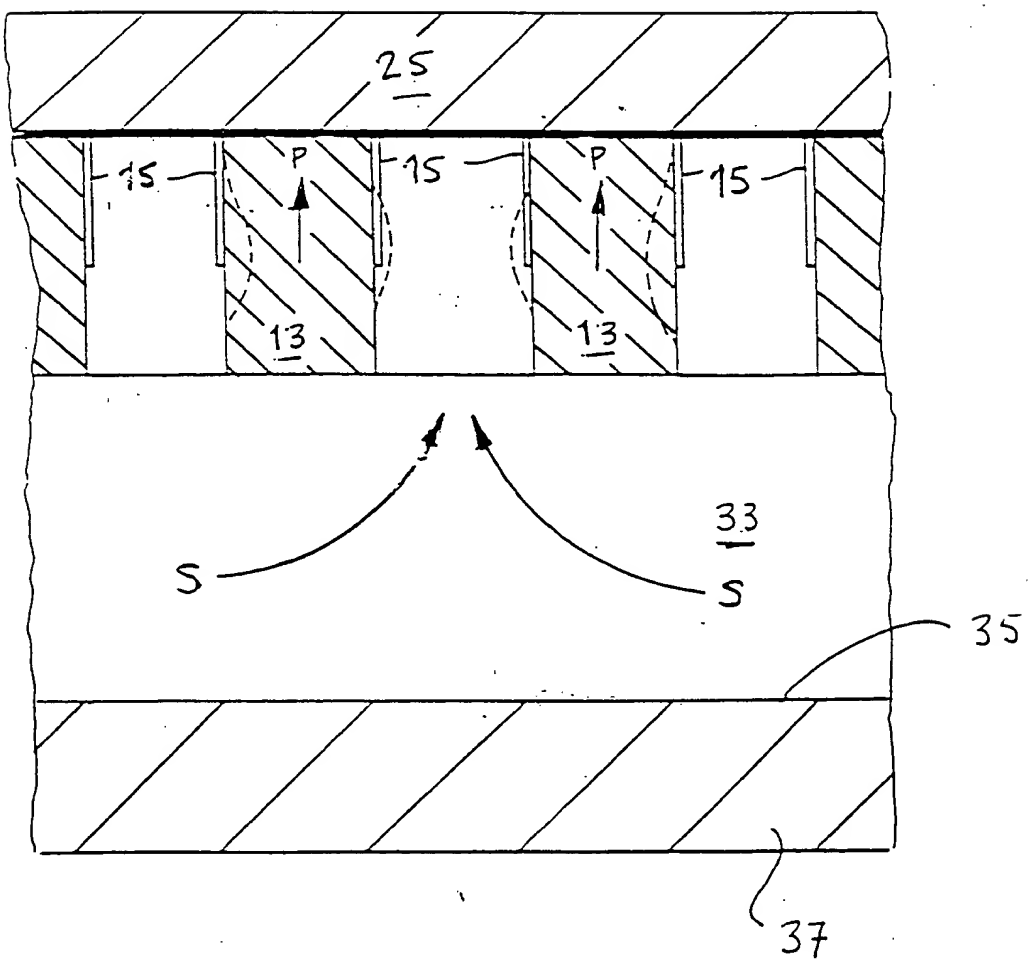

Fig. 3

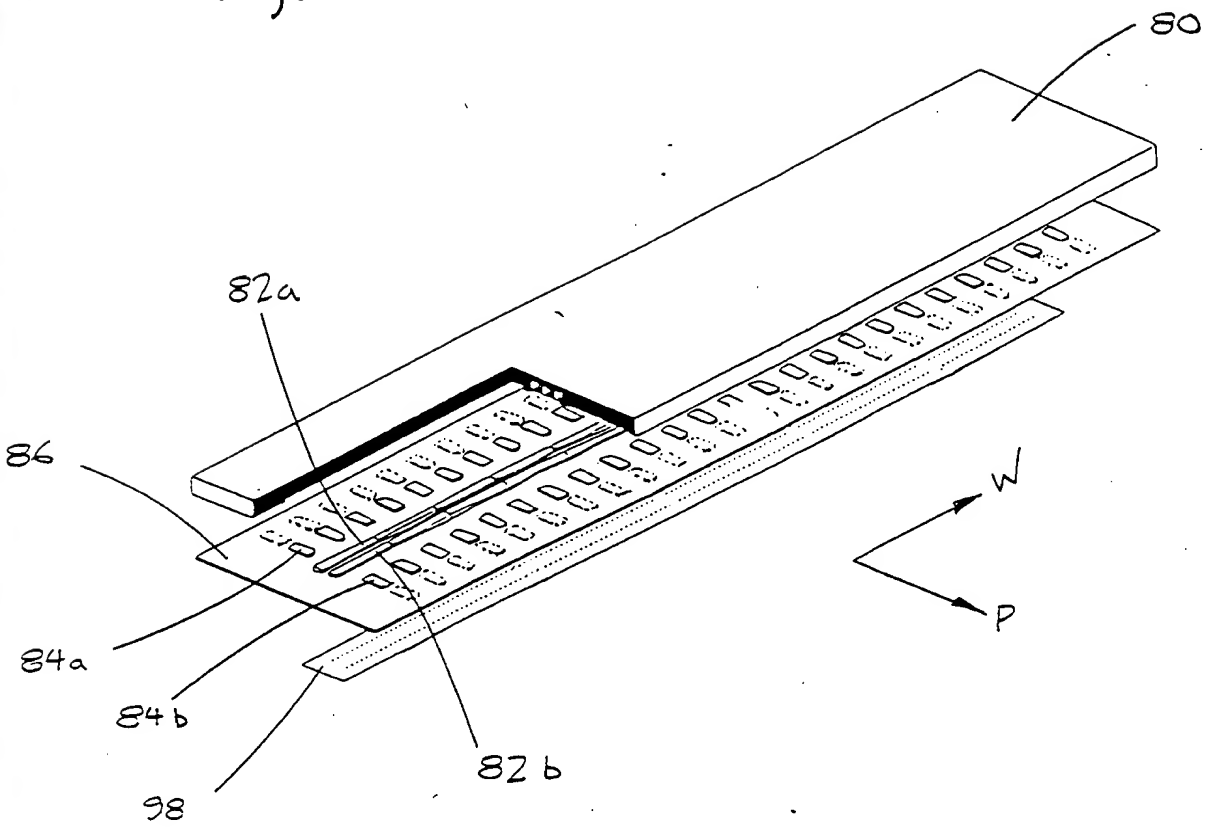
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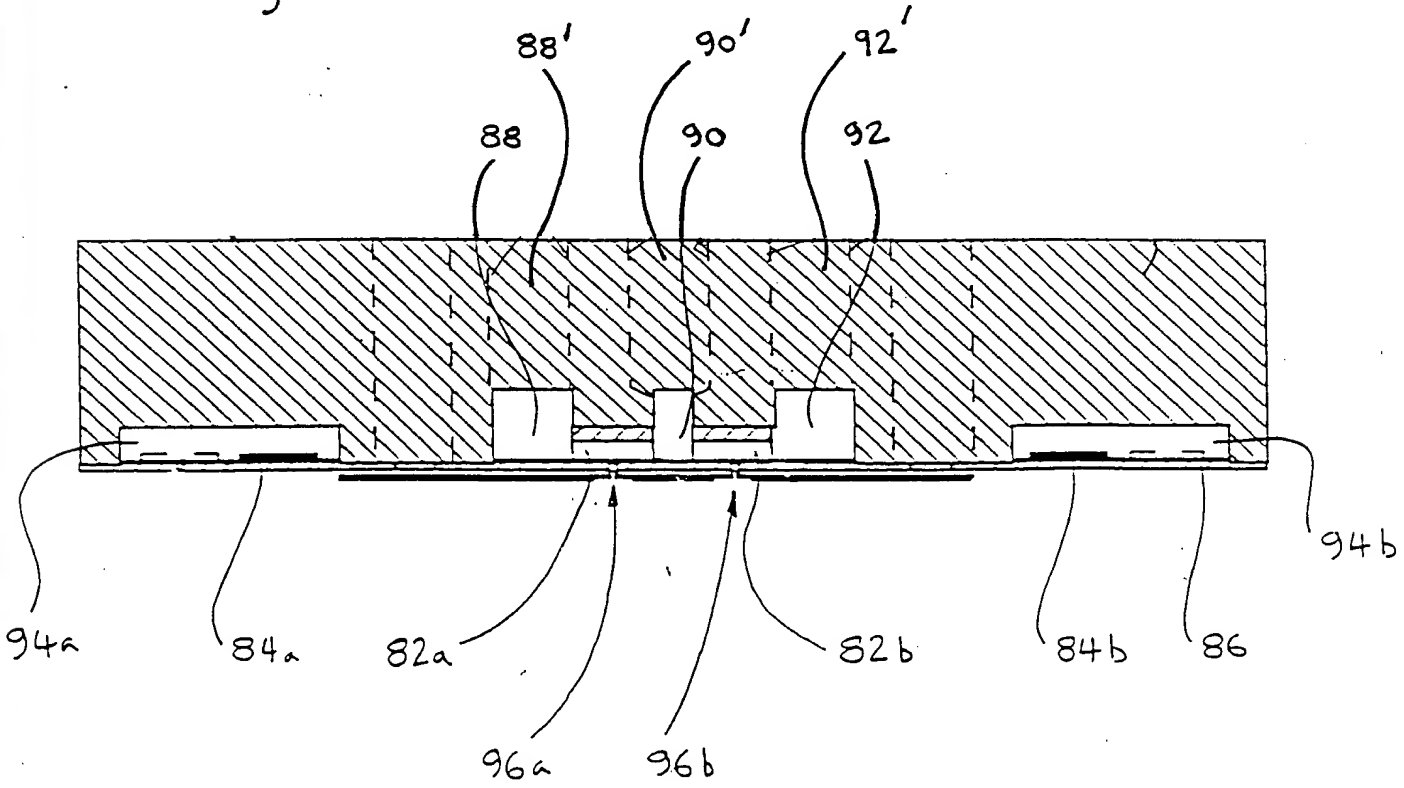
Fig. 4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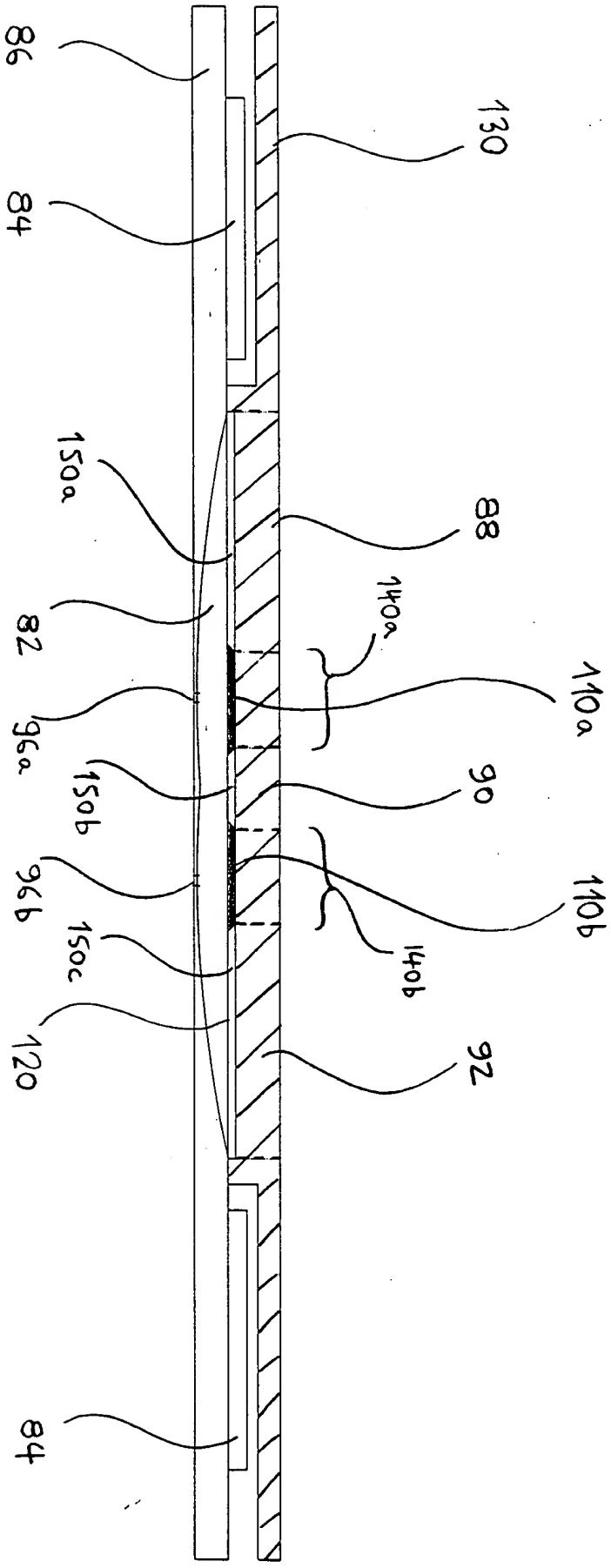
96b

Fig. 5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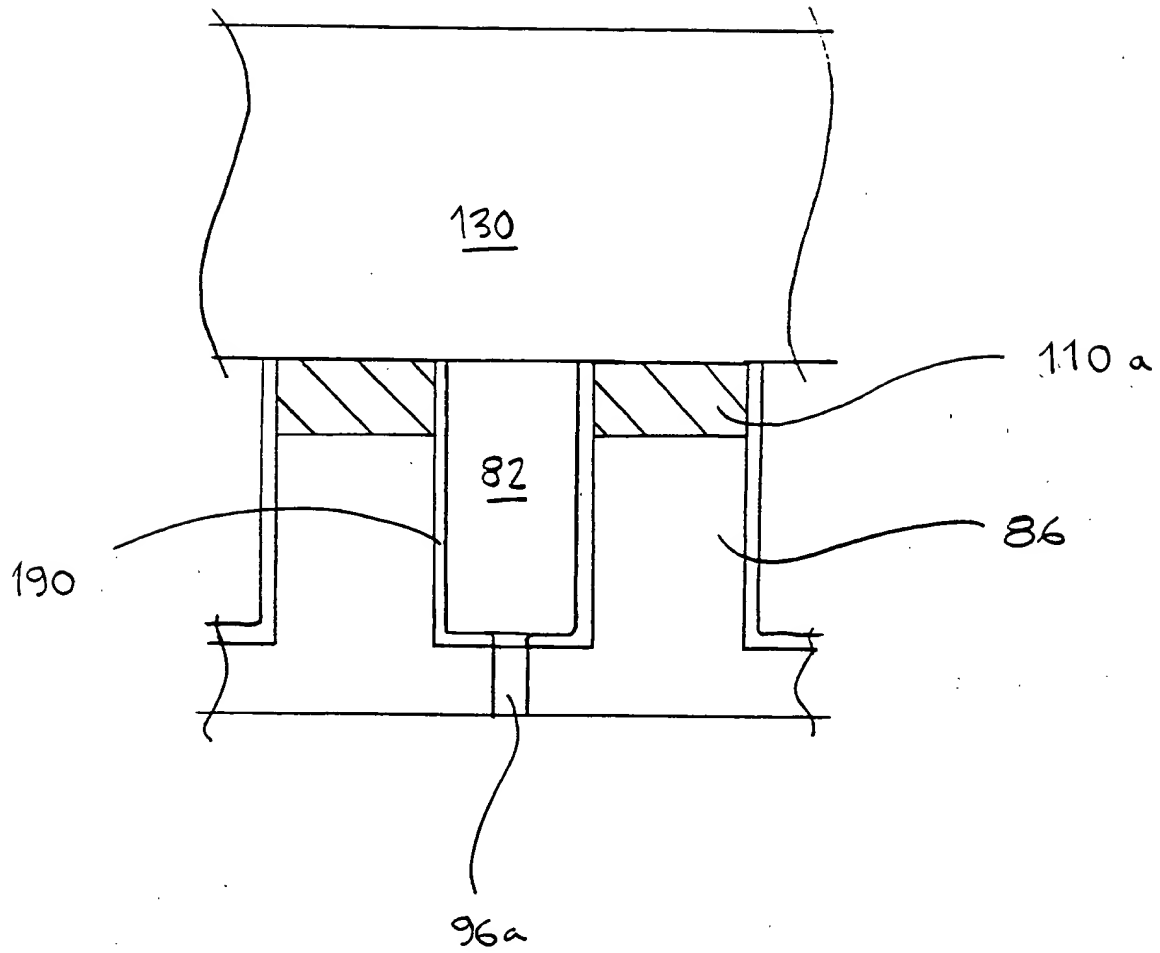
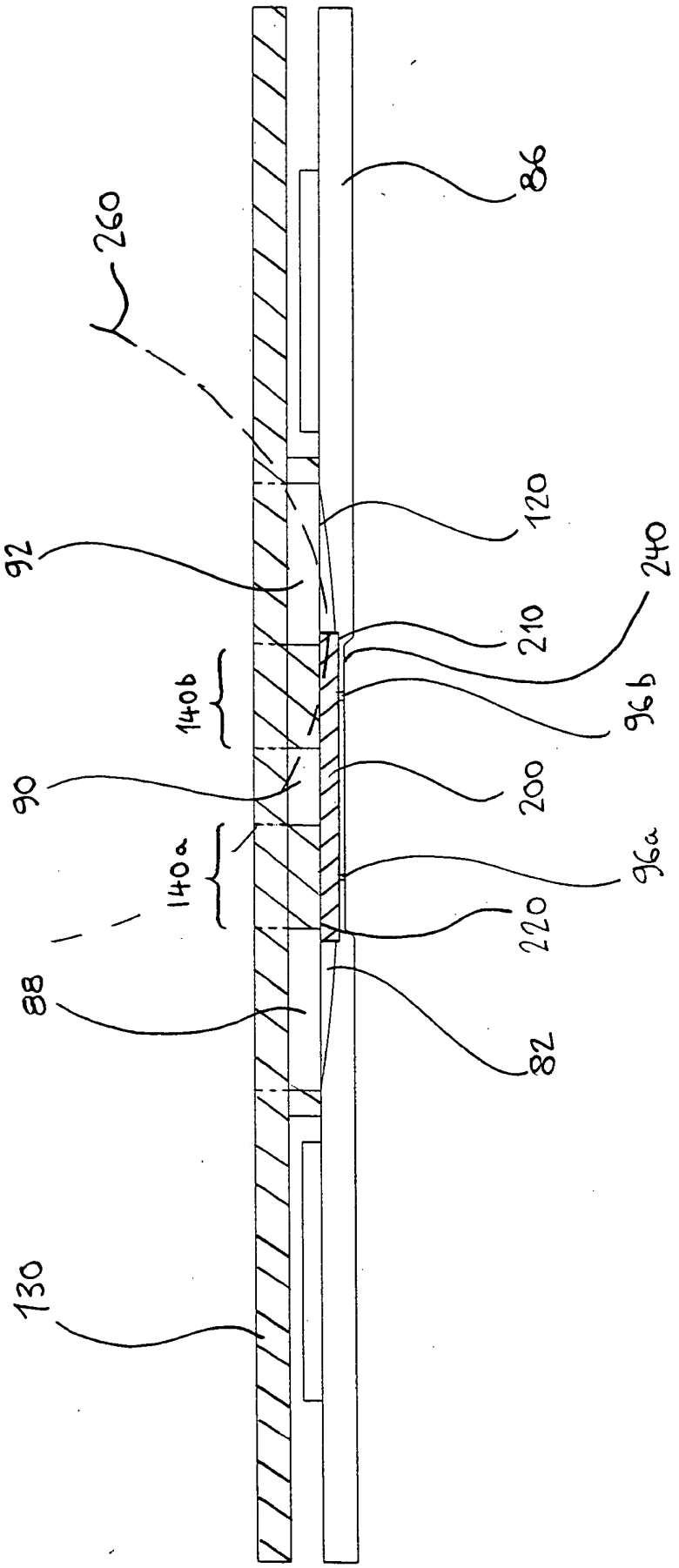


Fig. 6

Fig. 7



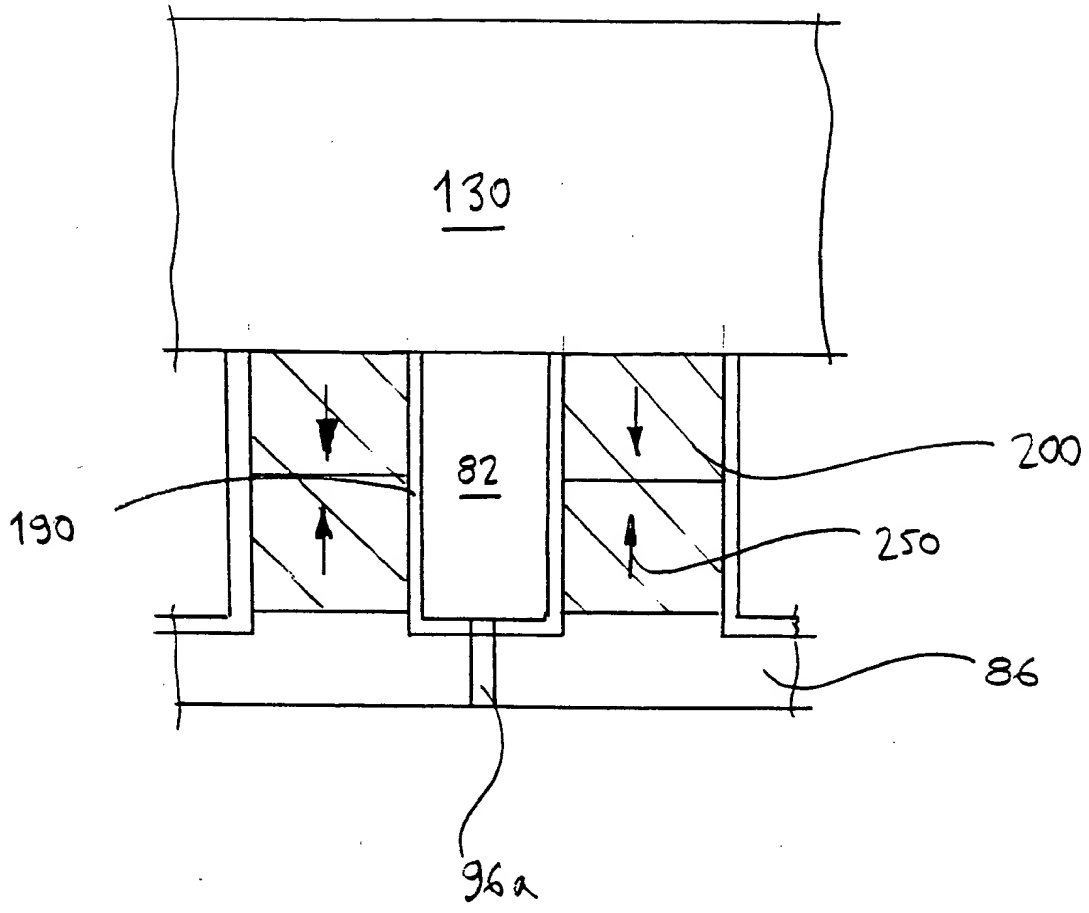
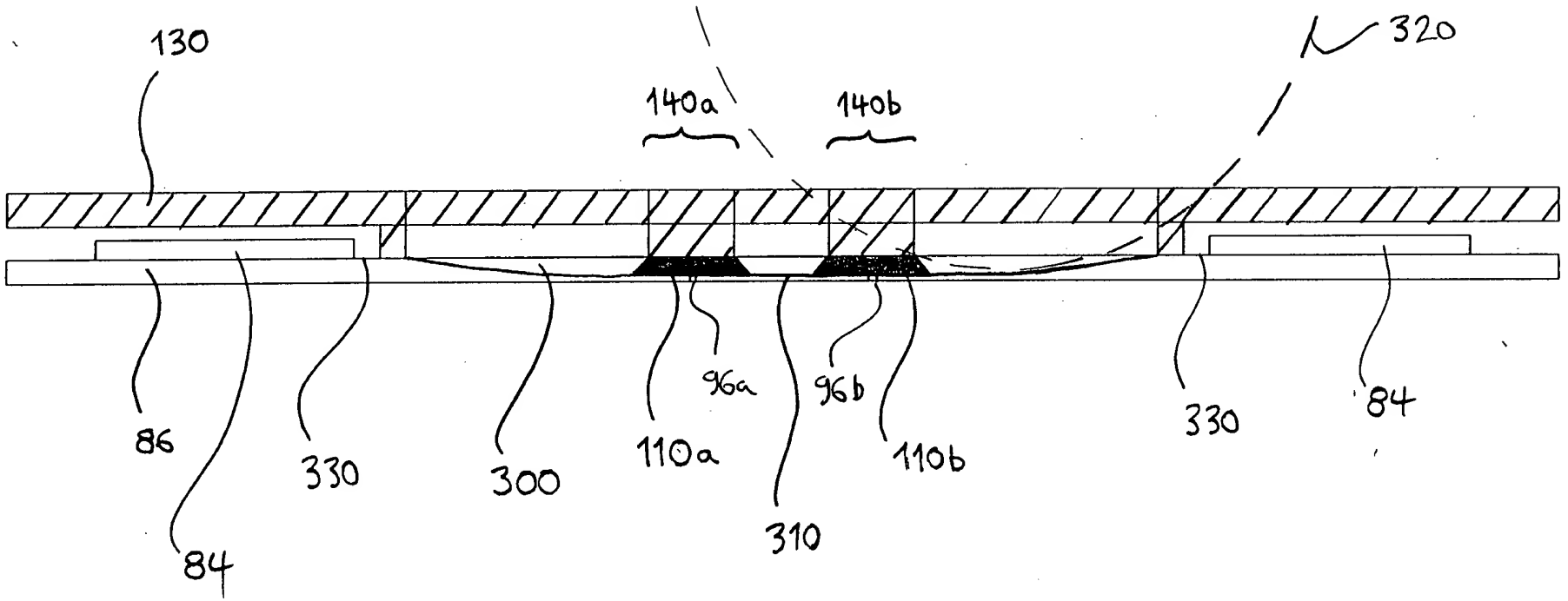


Fig. 8

Fig. 9



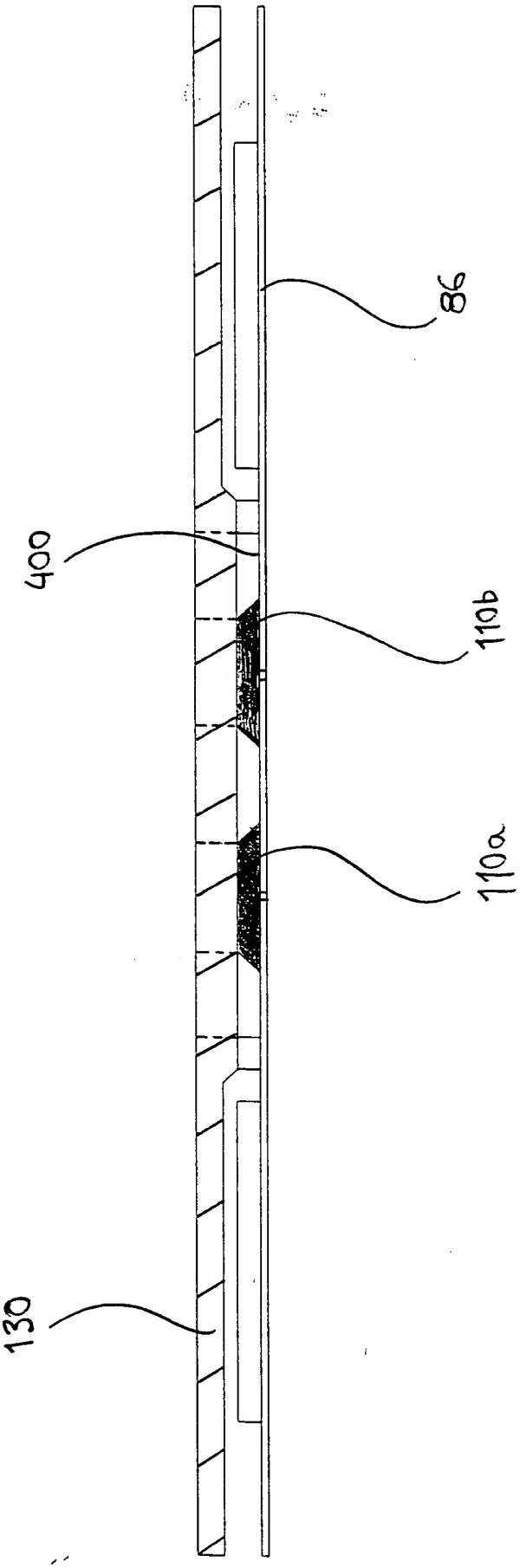


Fig. 10